COMPUTATIONAL MODELS OF EXERCISE ON THE ADVANCED RESISTANCE EXERCISE DEVICE (ARED)

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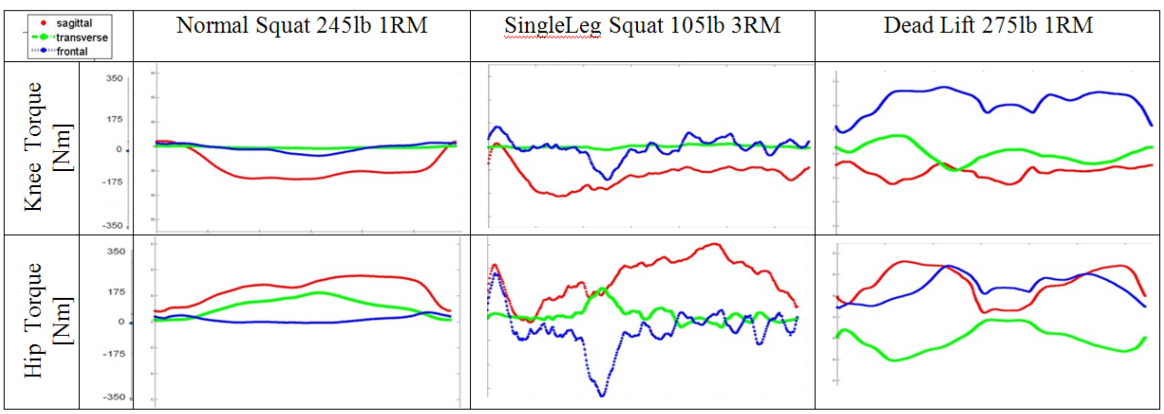
INTRODUCTION: Muscle and bone loss remain a concern for crew returning from space flight. The advanced resistance exercise device (ARED) is used for on-orbit resistance exercise to help mitigate these losses. However, characterization of how the ARED loads the body in microgravity has yet to be determined. Computational models allow us to analyze ARED exercise in both 1G and 0G environments. To this end, biomechanical models of the squat, single-leg squat, and deadlift exercise on the ARED have been developed to further investigate bone and muscle forces resulting from the exercises.

METHODS: All models were developed using LifeMOD software. The models are based on motion capture and ground reaction force data collected from a subject performing exercise on the ground-based ARED. The body of the computational model was scaled using anthropometric measurements obtained from the subject. The model contains 90 muscle groups in the lower extremities. Several of these muscles were scaled in the model according to cross-sectional areas obtained from a Magnetic Resonance Imaging (MRI) scan of the subject. Inverse kinematics simulations from the motion data were performed to calculate joint angles. The muscles and joints of the model were then trained using a proportional, integral, derivative (PID) closed loop control method. The calculated kinetics from the muscle (or joint) training were then used to drive a forward dynamics simulation. The predicted kinematics from this simulation were then validated against the actual kinematics.

RESULTS: For each exercise, both a joint torque driven and muscle force driven forward dynamics solution were found that matched the inverse kinematics of the exercise. The figure below illustrates the resulting 3-dimensional joint torque profiles for the knee and hip for each type of exercise. Of interest is that the absolute torque for the normal squat in the sagittal plane of the knee and hip can be achieved in the single leg squat with a lighter total load. Higher frequency content is also evident in the single leg squat torque profiles, suggesting single leg exercise requires stabilization. Muscle force profiles will be discussed further in the poster presentation.



CONCLUSION: Computational models of exercise are a useful tool for investigating the muscle and bone forces resulting from exercise motion. There is no other non-invasive technique for identifying these forces. For effective space-flight exercise countermeasure development it may be essential to understand the loading profile of different exercises. This understanding may be especially needed in this field given that the ARED is a unique piece of exercise hardware, and that exercise in microgravity may vary substantially from similar exercises performed on the ground. The computational models developed here help quantify the joint torques and muscle forces produced during exercise on the ARED in a 1G environment. The models point to several interesting findings and could be extended in the future to examine these same movements in microgravity. They could also be used to vary exercise form, cadence, or load in an effort to optimize an exercise for a specific muscle or at a specific bone location.